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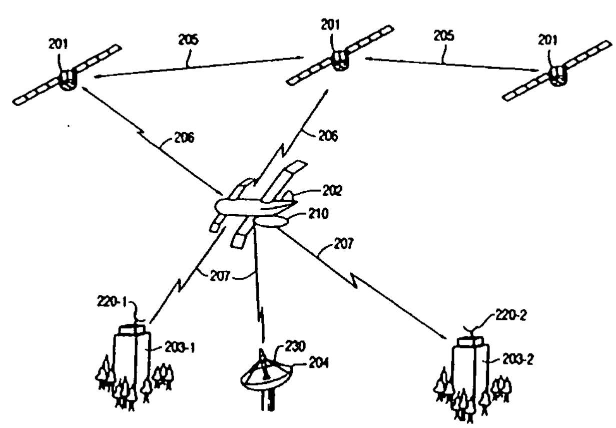

(57) Abstract

A network is provided to enable wireless broadband communication services to provide connectivity between users anywhere on the Earth that are both within and beyond a geographic area by utilizing millimeter and microwave carrier frequencies with wide bandwidths. An atmospheric platform carrying a payload serves as the main node of a star-topology network. The atmospheric platform communicates with other elements of the network such as Earth-bound user equipment, in multiple units, and gateways for providing information paths to remote cities. The network may also be used in accordance with a satellite network and with existing communications infrastructure. Because the atmospheric platform is flying above the earth, the network maintains communications links between the various elements of the network.

*(Referred to in PCT Gazette No. 22/2000, Section II)

Network For Providing Wireless Communications Using An Atmospheric Platform

FIELD OF THE INVENTION

The present application is a continuation-in-part application of Serial Number 08/966,973 filed November 10, 1997, claiming priority to provisional patent application Serial Number 60/057,787 filed September 8, 1997, which are both hereby incorporated by reference. According to the present invention, a novel network provides wireless communications, such as voice, data, images, video, and multi-media services, to a geographic area large enough to encompass a city and its neighboring communities. The network of the present invention can provide broadband and narrowband data services to subscribers and utilizes both microwave and millimeter wave (MMW) carrier frequencies with wide bandwidths available.

An atmospheric platform flies in the atmosphere high above the geographical area receiving the communications services. The atmospheric platform serves as the main node of a communications network, as described herein. Typically, the atmospheric platform functions as a "hub" of a wireless communications network for broadband services. For narrowband wireless services, such as fixed wireless telephony (also known as wireless local loop) or mobile telephony, the atmospheric platform typically functions as a switching "hub" or as a relay or concentrator of the narrowband data traffic. In all cases, the atmospheric platform serves as the main node of the communications network.

User equipment units (UE), also called premise equipment, customer premise equipment, consumer premise equipment, business premise equipment, premise equipment units, and portable user equipment, are communications devices that enable users to communicate with the airborne hub through wireless links. These ground-based communications devices can be located at the homes and offices or other fixed locations or premises, or be mounted atop vehicles to connect users requiring a portable connection to the network, or be handheld depending upon the service being offered. Each user equipment unit has an antenna. For MMW carrier frequencies, the antenna includes systems and circuitry for

pointing its main signal lobe at the moving atmospheric platform when transmitting and receiving communications signals, in order to maintain the highest possible gain of the signals being transmitted to and received from the moving atmospheric platform. When MMW carrier frequencies are used, the user equipment antenna can have an unobstructed view of the atmospheric platform due to the high operating altitude of the atmospheric platform. For microwave carrier frequencies, antenna pointing may or may not be required, depending on the particular service to be provided, as is known in the art.

The network has a star-topology configuration with the atmospheric platform serving as the main node of the communications network. User equipment units within the signal footprint (i.e., the region being served by a particular atmospheric platform) can communicate with each other via the atmospheric platform. One or more gateways provide information paths from the user equipment units within the signal footprint to locations beyond the geographic area being served by the particular atmospheric platform providing the signal footprint. Two wireless signal links are required: one from the user to the atmospheric platform, and the second from the atmospheric platform to the gateway.

The network of the present invention can also be used to link user equipment units located anywhere on the planet through the use of atmospheric platforms stationed between a satellite network and the terrestrial users.

The network of the present invention is particularly advantageous when employed in wireless broadband communications and wireless narrowband (e.g., telephony) communications, including mobile, portable and fixed services.

BACKGROUND OF THE INVENTION

Throughout this decade and the prior one, due to the proliferation of computers and computer networks, the worldwide appetites for timely information and effective communications services have grown at geometric rates. In recent years, new communications services have become well established (e.g., the Internet, faxes, modems, pagers, cellular telephones, video and imagery transacted over data networks, voice over the Internet, corporate intranets, etc.). In response to this rapidly growing demand, new

technologies and systems, both hardware and software, are being evolved, with steadily improving performance, to deliver voice, data, text, sound, and video at higher speeds and decreasing prices.

The demand for broadband communications services is also exploding. As used herein, a broadband communications network is defined to be a network that is able to provide equivalent bit rates between any two users high enough to allow streaming of compressed, full-screen video. Typical bit rates would be measured in a multiple of megabits per second, i.e., greater than 1 Mbps; a rate far greater than the tens of kilobits per second, e.g., 28.8 Kbps, now commonly offered to the mass market through a local telephone network. Consumers and businesses are demanding the ability to connect extemporaneously with other users within and outside their city at broadband rates, in analogy to placing an ordinary telephone call, in order to conduct sessions at broadband rates, at attractive prices, wherein they can exchange video, data, text, and images.

For example, users in Los Angeles, who have stressful commutes to their corporate offices want access to a broadband communications network that will allow them to work from their homes, and it will allow multi-media conferencing (involving voice, sound, text, data, imagery, and video) with their co-workers at the corporate offices so that they can collaborate effectively and efficiently, and be able to rapidly exchange large information files. Other examples of broadband communications extending over a distance scale of a large city and its neighboring communities include broadband connections between local government offices, health facilities, civil services, and direct connections to broadband and wideband long distance communications lines achieved by "jumping over" the local loop.

Broadband communications are being delivered through wired and wireless connections in the prior art. In the former, users are linked by either twisted copper wire pairs, coaxial cable, or optical fiber, or a mix thereof. Though individual broadband connections with these types of links can be made to be highly reliable, the capital cost required to create a fully integrated broadband network serving the entire geographic area can be exorbitant, especially in an area with aging communications infrastructure. For example, the regional telephone networks, referred to as "legacy networks", were optimized for carrying analog voice signals in the local loop; they will require substantial upgrades to carry

broadband communcations, especially at network nodes where the data traffic must be multiplexed, switched, and/or routed. In geographical areas without a prior wired infrastructure, the cost of installing or "green fielding" a new wired metropolitan-scale network will be high. In summary, the cost to provide a wired broadband network with coverage and access equivalent to the network of the present invention can be relatively high.

Several types of wireless broadband networks are being developed and deployed. One type, a terrestrial point-to-multipoint network, involves either erecting and operating multiple towers, each equipped with one or more "sectorized" antennas, or placing the antennas on the sides or atop of existing buildings or other manmade structures. Many antennas must be deployed throughout the area to be served. Wireless signals are sent and received between users and a nearby antenna, that serves as a network node, and then the data must flow between such nodes, either directly through broadband wireless point-to-point "backhaul" links or indirectly through the wired infrastructure, in order for the network to arbitrarily interconnect users throughout the geographic area.

An example of a wireless broadband network of this character is the Local Multipoint Delivery System (LMDS). Each node provides signal coverage to a small area within the larger geographic area containing the city and its surrounding communities. Within the area to be served by a given node, service may not be uniformly available and it may be restricted to disjointed "patches" due to blockage of wireless signals by foliage, buildings, and other obstructions both man-made and natural. In other words, service may not be available to homes and businesses located between such patches. If so, the incremental cost to extend service to such homes and businesses can be very high.

In contrast to the network of the present invention possessing a star-topology, the LMDS network has a "mesh" topology and consequently it requires many broadband links for interconnecting many nodes. A disadvantage of a tower-based wireless broadband network is that each node provides coverage to a small area, typically on the order of multiple city blocks. Hence, many nodes, often on tall towers, must be deployed to serve a large population of users who are distributed throughout a geographic area of the scale of the network of the present invention. Deploying multiple towers is expensive; and to have many

tall towers concentrated in a given geographic area can spoil views of the cityscape and the horizon, thus offending local communities.

Another type of wireless broadband communications network uses satellites to interconnect users on the ground (also labeled as either ground-based, Earth-bound, or Earth-based in this document). A variety of satellite designs and constellations of satellites can be used. The altitudes selected for deploying constellations of satellites include Low-Earth Orbit (LEO), Medium-Earth Orbit (MEO), Highly Elliptical Orbit (HEO) and Geosynchronous or Geostationary Earth Orbit (GEO). Each satellite of such a wireless broadband network can cover a geographic area larger than the network of the present invention, but nonetheless suffers from several limitations.

A first limitation is that the satellite will have severe constraints on its data capacity, i.e., the total information throughput of its communications subsystem for several reasons. First, its power generation capabilities will be typically less than several hundred watts per square meter of solar panels and the size of the entire solar array will be limited by practical considerations regarding launch and orbital deployment, and, for LEO satellites, orbital drag effects. In addition, its antenna aperture typically will be less than several meters due to mechanical considerations related to launch and orbital deployment. Moreover, its orbital path will be located at a great distance from the end user and its communications signals will be required to travel through the entire atmosphere to reach the users.

Another limitation to using satellites to interconnect users on the ground is found in the fact that deploying the satellite can be expensive, for it requires a risky space launch. Moreover, because satellites cannot be easily serviced or upgraded, a satellite communications network launched today must be able to satisfy minimum performance requirements on orbit typically for a duration of five to ten years without modification. Thus, satellites must be over-designed with spare components and redundancy.

Another segment of the wireless communications market experiencing unprecedented growth is telephony. Two generic deployment schemes are used: (1) cellular telephony for mobile users (known as cellular or PCS) and (2) wireless telephony to fixed locations such as homes or businesses (known also as fixed wireless telephony or wireless local loop). In many

developed countries, the mobile wireless telephony market is growing at high rates. To respond to the growing demand, many network nodes must be deployed; i.e., many towers must be erected or else antennas must be placed on the sides and tops of buildings. A typical city may require several hundred nodes in order to provide sufficient coverage and capacity. Such nodes are expensive to build and to interconnect. Furthermore, they have the disadvantage of establishing fixed service locations and are expensive to re-deploy and reconfigure as populations shift or as market demands change.

Fixed wireless telephony is enjoying a niche in developing countries, where wired telephony infrastructures do not exist. A quick and easy way to provide the population of those countries with basic telephone services is to install a fixed wireless telephony network. Wireless telephony eliminates the need to bury cable and/or string bundles of copper wire to connect the end users to the network. However, wireless telephony requires deploying many network nodes on the ground, which suffers from the same disadvantage noted above for LMDS or other wireless braodband networks, or depends upon satellites whose subscribers must then be willing to accept high phone calling rates and charges.

Therefore, a need exists for a new type of wireless communications network that can provide both broadband and narrowband wireless communications services.

SUMMARY OF THE INVENTION

According to the present invention, a novel network provides wireless communications between earth-bound user equipment units. As described in parent applications Serial Number 60/057,787 and Serial No. 08/966,973, a wireless communications system is provided in which atmospheric platforms are stationed between a satellite system and user equipment units in order to provide connectivity between Earth-bound users anywhere on the planet. Alternatively, Earth-bound users can communicate through the atmospheric platform which in turn communicates through a gateway, as further described. The present invention is directed to a network for supporting wireless communications as described in patent application Serial Nos. 60/057,787 and 08/966,973.

The network of the present invention is used to supply a geographic area, typically a metropolitan area, with wireless communications services using microwave and/or millimeter wave carrier (MMW) frequencies with wide available bandwidths. Such a network can be used for providing wireless communications services, for example, to 'super-metropolitan areas' which are 10's to 100's of miles in diameter from a single atmospheric platform.

Components of the network according to the present invention include multiple user equipment units (also called customer premise equipment, consumer premise equipment, business premise equipment, premise equipment units, and portable user equipment) on the ground and each with its own antenna, with tracking capabilities if required by the service to be provided as is known in the art; an atmospheric platform carrying a payload composed of wireless communications components and requisite interfaces (both hardware and software); and one or more gateways serving the entire population of users. The network has a star topology configuration with the atmospheric platform carrying the communications payload serving as the main node of the communications network. In other words, the atmospheric platform carrying the communications payload serves as the center point of a star configuration, with the other elements in the network each having a direct link to the main node.

More specifically, an airborne wireless communications network for serving a geographic area is provided which uses an atmospheric platform whose payload provides point-to-point interchanging, multi-casting, and broadcasting of messages to users distributed throughout a geographic area as well as to users beyond the geographic area serviced by the atmospheric platform. The atmospheric platform is preferably a special-purpose airplane that carries a large radio frequency payload which allows ground-based users to be interconnected. More specifically, the atmospheric platform of the present invention is preferably a piloted or unpiloted aircraft which has been approved for operation by the Federal Aviation Administration (FAA) and can operate from regional airports suited to small business jet and general aviation traffic. Most preferably, the aircraft is a manned high altitude long operation aircraft designed to fly above significant weather and within a narrow band of altitude (relative to its operational altitude) around a fixed point. The altitude band may be 10,000 feet in height with the minimum altitude being above typical commercial airline traffic, excluding the Concorde.

Messages are carried as modulated signals over microwave and/or millimeter wave carrier frequencies. The network connectivity between the user equipment, the atmospheric platform carrying the payload, and the gateway for providing connections both within the footprint and to remote areas are the basis for this invention and offer a unique communications architecture for transacting data, text, images, voice, sound, video, video-teleconferencing and other forms of multi-media information streams and the like, worldwide.

Further according to the present invention, the payload carried by an atmospheric platform is provided with an antenna array, digital switching and network management circuitry, as well as all other components, subsystems, hardware and software, necessary to offer wireless communications from a payload carried by an atmospheric platform.

The network of the present invention provides numerous benefits over communications networks of the prior art. First, the use of atmospheric platforms in the network of the present invention offers the advantage of ample power offered by combusting fuel. Second, such platforms can operate above usual civilian and commercial air traffic and harsh weather. Third, they operate above most of the air mass of the atmosphere and its precipitation and hence do not have flight performance impacts due to adverse weather factors. Fourth, they are able to communicate with diverse satellites in a variety of orbits by using electro-magnetic carrier frequencies ranging from millimeter waves to near-Infrared light, because of a clear line of sight, low absorption losses of signals by atmospheric gases, and low losses of signals due to scattering by raindrops and ice crystals.

The use of atmospheric platforms in the network of the present invention further allows for easy systems-level upgrades and customization, as improvements of the network's performance can be realized as often as needed simply by modifying the payload. In contrast, terrestrial wireless networks, such as LMDS or wireless local loop, require all communications nodes to be modified before the entire service area will be similarly upgraded. Satellite-based networks are disadvantaged because once a satellite is deployed, servicing and upgrading may be very expensive, if even possible. In contrast, all customers can be upgraded and/or customized at once with the network of the present invention. In addition, since the network of the present invention is arranged with a single node in a star

topology, it is easier to diagnose, inspect, repair, maintain, upgrade, improve, and enhance compared to the prior art.

The network of the present invention is particularly useful in broadband and narrowband communications markets, serving the needs of users requiring fixed, portable, and mobile communications services.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 is a diagram depicting the general architecture of the network according to the present invention.

Figure 2 is a diagram depicting communication between users using the network of the present invention.

Figure 3 is a diagram further depicting communication between users using the network of the present invention.

Figure 4 is a diagram depicting geographic coverage provided by the network of the present invention.

Figure 5 is a diagram depicting the atmospheric platform used in the network of the present invention as it travels around a point in the atmosphere.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

According to the present invention, a network is provided for facilitating wireless communications between any number of ground-based user equipment units. Referring to Figure 1, the network includes at least one atmospheric platform 102 which serves as the main node of a wireless communications network. Typically, the atmospheric platform functions as a "hub" of a wireless communications network for broadband services. For narrowband wireless services, such as fixed wireless telephony or mobile telephony, the atmospheric platform typically functions as a switching "hub" or as a relay or concentrator of the narrowband data traffic. In addition, the network includes ground-based user equipment units (103-1 and 103-2 in the example), also referred to as customer premise equipment, consumer premise equipment, business premise equipment, premise equipment units, and portable user equipment, each having a tracking antenna (120-1 and 120-2, respectively). If

required by the service to be provided, each antenna may possess a tracking system for pointing its main signal lobe at the moving atmospheric platform. The user equipment units enable an individual user to access communications services offered through the atmospheric platform 102, as well as one or more gateway 104 which enables the flow of information from the atmospheric platform to locations within and beyond the geographic region served by the network. Atmospheric platform 102 carries a payload 110. Tracking antenna 120-1 and 120-2 mounted on ground-based user equipment units 103-1, 103-2, respectively, have an unobstructed view of the atmospheric platform 102 due to the altitude of the atmospheric platform, as further described. In addition, gateway 104 also has a tracking antenna 130, typically larger than the antennae used by user equipment, which similarly enjoys an unobstructed view of the atmospheric platform 102, also due to the high altitude of the atmospheric platform. In Figure 1, two ground-based user equipment units are shown for simplicity. In practice, it is understood that numerous user equipment units will be used and serviced by the atmospheric platform; many will be at fixed locations, while others may be portable or mobile. Similarly, although Figure 1 shows a single gateway 104, it is understood that multiple gateways could be employed.

In a preferred embodiment, the atmospheric platform of Figure 1 is a manned aircraft. A manned aircraft offers distinct advantages over unmanned aircraft or another aeronautical platform (such as a balloon). Specifically, because wireless communications services are typically required over a metropolitan area, it is preferable that the atmospheric platforms be capable of being operated from regional airports associated with general aviation and business jet operations, instead of international airports. Typically, unmanned atmospheric platforms that operate, for example, through robotics or tele-robotics methods of control, are not allowed to land at civilian, commercial, and regional airports due to safety considerations of air traffic operating in the volume of airspace near the airports. Thus, atmospheric platforms that are manned aircraft are preferred. In this way, the present invention is capable of taking advantage of existing regional airports, and thus avoids the need to build special-purpose airports in order to provide communications services. However, it should be noted that the network of the present invention may be used with atmospheric platforms in the form of unmanned aircraft as well. Whatever type of atmospheric platform is used, it travels above the area for which it provides service. For each service (or multiple services) provided, the atmospheric platform flies within a chosen volume of airspace as dictated by the requirements

of that service or services. The atmospheric platform includes systems necessary to monitor and control its flight within that volume of airspace in order to provide the desired service or services.

Figure 2 shows the network architecture of Figure 1 in use. Referring to Figure 2, a communications system is provided in which ground-based user equipment units 203-1 and 203-2 (respectively including antennas 220-1 and 220-2) can be interconnected in a manner which allow them to communicate at very high data rates. Atmospheric platform 202 carrying payload 210 in Figure 2 is located above the Earth at high altitudes in the atmosphere, typically above the commercial airspace. More specifically, the location of atmospheric platform 202 must be above the flight corridors of commercial airlines, excluding the Concorde trans-continental supersonic passenger airline, and general aviation air traffic and above adverse weather. It is preferred that the atmospheric platform 202 be located at least 50,000 feet above mean sea level.

Atmospheric platform 202 typically flies in shifts over a particular area requiring communications services. For example, a particular atmospheric platform 202 might fly over an area for an eight-hour shift, at which time a second atmospheric platform (in turn, carrying its own payload) would take over for a second eight-hour shift, followed by a third atmospheric platform (again carrying its own payload), perhaps the same platform used in the first shift, for a third and final eight-hour shift in a 24-hour cycle. When a new atmospheric platform is about to take over at the end of another atmospheric platform's shift, the two atmospheric platforms both typically fly within the same altitude band, i.e., within a range of several thousand to ten thousand feet, required for communications according to the present invention over the geographic area to be served, until systems control, operations, and user communications are passed from the retiring atmospheric platform to the arriving atmospheric platform. Thus, the atmospheric platforms used with the present invention operate in overlapping shifts to provide continuous service to an area, 24 hours per day, 7 days per week.

Payload 210 of atmospheric platform 202 houses all elements required for an airborne communications network. More specifically, the payload 210 contains an antenna array, an electrical power generation capability, on-board switching, receive and transmit radios, signal

modulators and de-modulators, an electrical power conditioning and distribution buss, environmental control and thermal conditioning, position and attitude sensing, as well as all other components, systems, hardware and software, necessary for providing reliable point-to-point and point-to-multipoint wireless services to a large geographic area from a single communications network node, as known in the art.

The payload 210 may include diagnostic equipment for performing periodic spot checks of the operations and system performance of the communications network and a graphical user interface for a copilot in the cockpit of the atmospheric platform to reference, in order to view results of the operations and systems checks. Data related to operations and systems performance may be relayed to the ground. Moreover, because the atmospheric platform is manned, the copilot can supplement relayed data depicting system performance based on his own observations. Coupling operations data with pilot awareness ensures that the network of the present invention is a robust system.

As depicted in Figure 2, atmospheric platform 202 carrying payload 210 serves as the main node of a star-topology wireless communications network which includes multiple units of ground-based user equipment units 203-1, 203-2 and a gateway 204. In practice, a variable number of ground-based user equipment units and gateways can be used in the network of the present invention. The specific numbers of network components shown in the examples herein are only for illustrative purposes and are not intended to limit the network of the present invention. Payload 210 carries antennas, some of which generate a frequency reuse pattern within the geographical area or footprint being serviced by the atmospheric platform, as is known in the art.

Users within the same footprint are those users 203 which are served by the same atmospheric platform 202. According to the present invention, a service footprint is in a range of 10's to 100's of miles in diameter and is typically an area greater than 300 square miles. Such a footprint is defined to encompass a metropolitan area requiring wireless communications services. Referring to the figure, if user equipment unit 203-1 wishes to communicate with user equipment unit 203-2, user equipment unit 203-1 sends a wireless signal 207 to the atmospheric platform 202. The frequency of the signal 207 between the atmospheric platform and the user equipment unit must be such that the signal has acceptable

strength either when received or transmitted by the atmospheric platform. Depending upon the choice of the carrier frequency, the signal 207 may not be attenuated too strongly by rain droplets and atmospheric gases. In a wireless broadband communications system, it is preferred that the frequency of the signals 207 be under 100 GHz. In a wireless telephony system, it is preferred that the frequency of signals 207 be less than 10 GHz and above 500 MHZ to allow the use of inexpensive telephone sets. Thus, the present invention is capable of operating in a range of carrier frequencies from 500 MHz to 100 GHz of the electro-magnetic spectrum; at microwave and millimeter wave carrier frequencies with wide bandwidths, it can be capable of providing data rates greater than one megabit per second to a given user located within the service area. In addition, the network of the present invention supports multi-media communications, that is, it is able to transact video, images, voice, sound, text, and data, and combinations thereof.

Next, the atmospheric platform 202 carrying payload 210 communicates either directly with the other user, here user equipment unit 203-2, or with a gateway 204. Gateway 204 is connected either to the public switched telephone network, or to a fiber backbone, or to any variant of a wideband communications link, or to a wide area network, or to any other existing communications infrastructure, which can provide access, for example, to the Internet, or to destinations well beyond the service area directly covered by the atmospheric platform.

User equipment units 203 can communicate with other users outside of their own footprint by one of two methods. As in the example, user equipment unit 203-1 wishing to communicate with another user outside of his or her own footprint first sends a message to the local atmospheric platform 202 serving user equipment unit 203-1. Then, the atmospheric platform sends a wireless signal 207 to a gateway 204, again connected to either the public switched telephone network, or to a fiber backbone, or to a long-distance broadband or wideband link, which in turn conveys the message to a remote destination.

A second way for a user to communicate outside his or her own footprint is depicted in Figure 3. User equipment unit 306 communicates via signal 311 (for example, having a frequency appropriate for terrestrial wireless applications as signal 207 described with respect to Figure 2) to an atmospheric platform 300 carrying payload 310. The atmospheric platform

300 in turn communicates via wireless signal 312 with a satellite 301. Significantly, signal 312 can utilize a higher carrier frequency as compared to the carrier frequency used for linking the atmospheric platform and the user equipment unit (i.e., signals 311 in Figure 3 and signals 207 in Figure 2). Satellite 301 is one of several in a collection of satellites. At any given time, each atmospheric platform serving user equipment units within its unique footprint has an associated satellite. In the present example, satellite 301 communicates via wireless inter-satellite links (ISLs) or wireless signal 302 through satellite 303 to satellite 304. These ISLs 302 typically utilize wide swaths of spectrum at carrier frequencies much higher than typically utilized in terrestrial wireless communications. Satellite 304 then communicates via wireless signal 312 with its associated atmospheric platform 305 which includes payload 315. Atmospheric platform 305 services the user 309 with whom user 306 wishes to communicate. Atmospheric platform 305 communicates via wireless signal 311 to user 309 in footprint 310, thus effecting communications between users in different footprints that, for example, may be two metropolitan areas either within the same country or in different countries, continents apart. In this way, communications traffic can be "back hauled" or moved between diverse users in different footprints.

Through the use of multiple networks in accordance with the present invention, it is possible to provide wireless communications services between users at great distances, e.g., inter-continental distances, on the Earth.

Employing an atmospheric platform between the satellite and the ground offers particular advantages according to the present invention. First, referring to Figure 4, the present invention allows the satellite 401 and the atmospheric platform 404 carrying payload 410 to communicate via signal 403 which has a very high frequency, typically between 50 GHz to100 GHz for MMW carrier frequencies, or even at much higher frequencies such as laser light, for example, operating either in the near-Infrared (NIR), the midwave-Infrared (MWIR), and longwave-Infrared (LWIR) spectral bands. For each of the infrared bands, there are laser sources and receivers within the state of the art to be used in ISLs. These very high frequency signals are strongly scattered by moisture in the atmosphere, especially rain droplets and ice crystals for laser light frequencies and rain droplets for MMW frequencies, that occur with significant densities at altitudes well below the altitude band of the atmospheric platform of the present invention. Accordingly, these very high frequencies

were not used with the prior art methods, for example, where a satellite needed to communicate directly with the ground and not have its signal be highly affected by changes in weather. Hence, the present invention effectively utilizes previously unused higher electro-magnetic frequencies in which considerable bandwidth is available. Once the satellite 401 interconnects with the atmospheric platform 404 carrying payload 410 with the high-frequency signals 403, atmospheric platform 404 (carrying payload 410) can then use its own onboard power and antenna to essentially repeat or magnify signals at lower frequencies to communicate with ground based user equipment units.

Further, according to the present invention, the atmospheric platform, because of its abundant power, large antenna array and proximity to the ground relative to satellites is able to create a frequency reuse pattern with smaller beams in a multi-beam pattern 406, cellular-like in its geometry if desired, and to provide dedicated spot beams within the same given footprint 405. A frequency reuse pattern is a well known method of making efficient usage of spectrum to carry information; it allows the same signal bandwidth to be used multiple times within the service area corresponding to the signal footprint. Generally, the available spectrum is divided into frequency sub-bands that are projected from the atmospheric platform as separate beams. The number and sizes of the beams in a frequency reuse pattern depend upon the platform's altitude, antenna array size, the effective size of each antenna aperture, the frequency bands used, available power, and the switching and network management capabilities. The amount of throughput between a terrestrial user and an atmospheric platform can be much higher than between a terrestrial user and a satellite for the same premise equipment due to the shorter distance to the atmospheric platform. By providing more beams to a given service area with comparable signal bandwidth per beam relative to satellites, the atmospheric platform of the present invention can transact an amount of information per square mile or square kilometer of service area per unit of time much higher than a satellite.

Still referring to Figure 4, the payload 410 on atmospheric platform 402 can carry various types of antenna arrays. A first type of array is composed of many refractive lens antennas, either copies of the same basic design or slight variants of a common design differing in aperture gain or effective F-number, each providing multiple beams, used to create a beam reuse pattern, typically cellular-like if desired, as is known in the art and

described above, on the ground to cover the area to be served. A second type of antenna array has many single aperture "steerable" antennas, of a common design, each with a two-axis angular pointing mechanism, and is used for providing beams that can be steered to fill in holes that might occur in the cellular pattern, or to offer a wireless link to a user requiring a very high data rate on a dedicated basis. For example, if a beam in the reuse pattern created by the antennas of the first set becomes degraded, the steerable antenna can be used as a backup to fill in the hole developing in the beam reuse pattern. The steerable antenna can also be used to provide a beam that remains effectively stationary on the ground irrespective of movement of the atmospheric platform normal to its operations, and can thus offer a dedicated beam to one or more users within the beam spot being maintained on the fixed location on the ground.

More specifically, the beams arranged in the reuse pattern on the ground, typically cellular-like but not necessarily, that are created by the antennas on the atmospheric platform, may be fixed, i.e., stationary in their motion, either relative to the atmospheric platform or to the ground. When refractive lens arrays are used to create the reuse pattern, the beams are fixed relative to the atmospheric platform, and the reuse pattern will move (i.e., rotate and translate) on the ground while the atmospheric platform moves along its flight path. Information from the ground-based user equipment units are encoded and sent in packets to the atmospheric platform carrying the payload. The connection between user equipment units is handled by the payload equipment, specifically the software and switching capability, that perform the hand-off of the information path between beams as the pattern sweeps across the ground. The connections are made through signaling protocols adapted from practices of the terrestrial and satellite wireless communications industries, as is known in the art. In contrast, steerable beams remain stationary on the ground as the atmospheric platform follows its nominal flight path. However, on occasion, the platform may experience an anomalous flight condition wherein its angular orientation may change quickly and by a significant amount. In such a scenario, the connection between user equipment units is re-established by the payload equipment, specifically the software and switching capability, as the steerable beam is returned to its desired location on the ground. Thus, it is possible to employ both types of antennas at the same time. (When steerable beams are used, a circuit is created between the ground-based user equipment unit and the atmospheric platform carrying a payload such that information travels via the route created by the steerable beam.) Thus,

referring to the Los Angeles example noted above, and by way of example, the network of the present invention readily provides broadband communications in the form of data, video, images, voice, etc. between a employee, for example based at his/her home, and coworkers at the office in the same metropolitan area while offering easy servicing, upgradability and customization of the network.

Referring again to Figure 2, payload 210 also includes a commercial grade high-speed switch, either packet-oriented or connection (i.e., circuit)-oriented or both, at the core of the airborne switching configuration, containing I/O ports and surrounded by a set of identical edge switches providing fan-in/fan-out and dynamic switching of beam feeds for the core switch. As a result, the airborne wireless network hub can tolerate movements on the ground of the beam reuse pattern created by its airborne antenna arrays and can maintain communications by dynamically reassigning beam feeds. This approach effectively increases the number of ports of the core switch and relates to the task of so-called "soft handoffs," that is, beam feed reassignments. As a result, it is unnecessary to modify the functionality of a commercial high-speed switch at the core of the airborne switching configuration and results in affordable high-speed edge switches of proper functionality.

User equipment units 203-1, 203-2 can contain circuitry for sensing encoded pilot tones placed in the guard bands of a wireless communications band segmented into sub-bands through frequency division techniques to achieve frequency reuse in the reuse pattern, typically cellular-like in its geometry. Software effects sub-band hopping and coordinates the hopping with a remote communications network transceiver.

With the network of the present invention, the premise equipment needs to know what sub-band frequency it will be using to communicate with the atmospheric platform. One of several methods may be employed.

The first method is an analog "locally determined" signal processing method. The atmospheric platform can transmit a set of discrete frequency "pilot" tones, one for each sub-band used in a frequency division multiplexing (FDM) scheme for creating the beam reuse pattern, perhaps cellular-like, on the ground. The discrete tones can be located in the guard band regions between neighboring frequency sub-bands, for example, close to the lower

band-edge of the nearest sub-band, that can be thought of as its companion sub-band. Each communications beam composed of one communications frequency sub-band that is created by the antenna array on the atmospheric platform and sent to the ground, has its "companion" pilot tone.

The user equipment units include analog circuitry for sensing the entire set of pilot tones. The circuitry, through signal processing methods, measures the strengths of the pilot tones and analyses their variations over time. Through filtering methods standard to signal processing, the circuitry constantly determines which sub-band to select next and through a special data channel reserved for network control, the premise equipment then "coordinates" its hop to the next communications sub-band with the atmospheric platform.

A second method is a "coded" variant of the "locally determined" analog method described above. In the first method, each pilot tone in the set has a unique dominant frequency, and the broadband radio associated with the user equipment must "listen" across the entire communications spectrum bandwidth to simultaneously sense all of the pilot tones. Instead, a unique, orthogonal set of "coded pilot tones" can be created by using only one narrow slice of bandwidth, for example, in one guard band (perhaps the one lowest in frequency lying in the entire communications bandwidth), and by uniquely encoding each of the pilot tones desired for the set through modulation techniques. In essence, each "coded pilot tone" carries a unique identification number. With this method, the premise equipment can have a frequency-stabilized sub-circuitry with narrow filters dedicated to extracting the set of coded pilot tones and determining their strengths and the time histories of their strengths.

A third method is a "pilot channel" variant of the "locally determined" analog method described in the first method. Each of the pilot tones now becomes a narrow bandwidth "control channel," a "pilot channel," which carries identifying and diagnostic information about its companion communications frequency sub-band. The information so provided is used by the user equipment for assessing bit error rates and the time history of the link margin characterizing the companion communications sub-band. The user equipment determines if and when to hop to the next communications sub-band and coordinates the action with the network management functions provided on the atmospheric platform. This method allows

the network to characterize the signal propagation quality of each beam by actively determining bit error rates of uniquely coded messages. When communicating with the atmospheric platform through a developing thunderstorm, each beam on the ground can intercept a unique amount of rainfall, and hence have a unique link margin and bit error rate. This method of actively sensing the beam propagation quality allows the network to respond on the basis of "intelligence" to changes in the signal quality of the beam pattern on a beam-by-beam basis.

A fourth method describes a "globally determined" method. The premise equipment can be equipped with memory and software to store a geometric map of the beam reuse pattern created by a wireless communications antenna array operating in the atmosphere or in space, i.e., an airplane or other type of atmospheric platform, or satellite. With this method, user equipment also includes systems for receiving the coordinates of the defining the beam pattern created by the atmospheric or space platform, through a narrow-band control channel, as described above, or through a set of narrow-band control channels, which when their signals or encoded data are received enable the user equipment on the ground to track the distant atmospheric or space platform and to select the proper sub-band of the communications bandwidth by interpreting the messages of the coded pilot tones and/or coded pilot channels.

Selection of one of the four methods described above is generally based on pragmatic considerations, such as cost, vendor availability, systems requirements and the like. The first method described is generally the easiest and most straightforward to implement.

Referring to Figure 5, the atmospheric platform according to the present invention can control its flight about a pre-selected path in the atmosphere through the use of a set of geographical way-points, which may be computed by equipment on the atmospheric platform that receives signals transmitted from a Global Positioning Satellite (GPS) system or from sources located at surveyed ground coordinates. The atmospheric platform can then broadcast its geographical coordinates (related to its latitude, longitude, and altitude or an equivalent set of spatial coordinates) to circuitry on the ground residing within each user equipment to be used for controlling the direction of the user equipment's high-gain antenna (and hence its communications signal beam). Through the use of the position coordinates so broadcasted by

the atmospheric platform, antennas on the ground can then be pointed to the atmospheric platform, in an open-loop control manner.

More specifically, an atmospheric platform may determine its position through the use of fixed ground reference points with known locations in concert with the GPS system as known in the art. Using multiple fixed, ground reference points, the atmospheric platform can use geometric techniques, such as three-dimensional triangulation, quaternion analysis, etc., as known in the art, to determine its position. By determining its precise location in this manner, the atmospheric platform is then able to accurately point its antennas to users at fixed ground locations.

An alternate way for the atmospheric platform to establish its position is through the use of multiple ground-based transmitters at known locations without reference to the GPS system. Such transmitters serve as reference beacons which allow the atmospheric platform to calculate its precise location, again by geometric techniques.

In essence, the atmospheric platform tells all of the user equipment in its service area "Here are the coordinates of my location." In turn, by knowing the coordinates of their locations, each user equipment unit can compute its unique direction to point so that its antenna's beam, like the light of an automobile's headlight, contains the atmospheric platform. This method of "informed location" obviates the requirement of having analog signal processing circuitry in the user equipment that must sense the maximum strength of the signal transmitted by the atmospheric platform, as a technique for pointing the user equipment unit antenna at the atmospheric platform. By explicitly utilizing position information so broadcasted by the atmospheric platform, the user equipment unit antenna can point to the atmospheric platform in an open-loop manner and be able to accurately point irrespective of large variations in the strength of the broadcasted signal caused by changes in the amount of rain intercepted along the broadcasted signal path connecting the antenna of the user equipment to the signal source on the atmospheric platform.

Because the atmospheric platform of the present invention preferably operates in shifts out of regional airports, the entire communications payload located on the atmospheric platform can be inspected immediately upon landing and on a routine basis. Diagnostic

equipment can be connected to the communications payload aboard the atmospheric platform upon landing in order to ensure that the communications payload is functioning properly. Thus, the network of the present invention can be easily maintained and upgraded, unlike satellite systems which can not be accessed after they are launched. Likewise, the network of the present invention also offers advantages over tower-based wireless systems which require each tower to be serviced individually, which is expensive and cumbersome; the former requires inspection and repair of a single hub whereas the latter requires technicians to visit many tower and other remote sites.

In addition to providing a unique ability to perform maintenance to the communications payload of the atmospheric platform, the network described permits a rapid upgrade of the communications payload to be implemented each time the atmospheric platform lands. For example, a first version of the payload carried by the atmospheric platform can be readily replaced with a second version capable of offering more capacity, thereby increasing the capacity offered to a geographic area. This aspect of the present invention also provides the ability to modify the on-board communications package on the atmospheric platform in order to provide custom features for a particular geographic service area.

For example, an airborne imaging system may be combined with the broadband communications system. If, for example, a particular metropolitan police department needs the ability to obtain high resolution video and images anywhere in the area serviced by the wireless communications network, still and/or video cameras could easily and readily be installed during daily routine access to the atmospheric platform. The known position of the atmospheric platform could then be used to steer the cameras to the desired location and the network of the present invention could be used to transmit the image data to the police department, for example. In the alternative, with such an enhanced system, a ground-based user can request that an image of the ground be taken by providing a GPS location. Airborne cameras located on the atmospheric platform automatically train a still or video camera on the specific GPS location and transmit that data to the user making the request through the network techniques previously described. Such an enhanced system combining airborne imaging with a broadband communication system offers particular advantages, for example,

to law enforcement organizations needing to record or monitor events at a particular location with a metropolitan area.

In an enhanced version of the network of the present invention, so-called "differential GPS" is employed. As is known, a GPS systems provides a latitude and longitude (i.e., location information) with a known level of accuracy, typically plus or minus 100 m depending on location on the Earth and weather conditions. If, for example, the exact location information is known for a particular point on the Earth and its GPS position is then determined, a difference between the exact location information and the GPS position will determine the error for the given system. With the enhanced version of the network of the present invention, the atmospheric platform knows its locations, determines its GPS position, calculates a difference which is then transmitted to various premise equipment units as a GPS correction value which can be employed to more accurately steer the antennas mounted on the user equipment units.

Further, according to the present invention, the atmospheric platform, because of its abundant power, large antenna array and proximity to the ground, allows the use of smaller user equipment antennas and hence less expensive user equipment relative to those used for communicating with satellites through communications links offering comparable bit rates. Also, the user equipment for communications with an atmospheric platform requires only one antenna. Whereas, the premise equipment for communicating with LEO satellites requires two antennas arrays, (either two mechanically steered antenna dishes or two electronically steered arrays), whereby the first antenna intercepts the next satellite as it ascends above the local horizon, and the second continuously follows the prior satellite in the orbital ring as it advances across the sky to the opposing (terminal) horizon. Since the rooftop portion of atmospheric user equipment with only one antenna is typically three times more expensive than the internal portion of that user equipment which connects to digital computers, the cost ratio of satellite user equipment with two antennas to the atmospheric user equipment with only one antenna is nearly twice as expensive.

Another advantage of the present invention is found in that it provides a disaster proof wireless communication system capable of withstanding earth quakes, serious wind conditions and the like as compared to the prior art.

The present invention is not limited to the particular embodiments described above which have been chosen to illustrate the invention, with reference to the accompanying drawings.

WE CLAIM:

1. A network for providing wireless communications between users, said network selectively connectable via wireless links with a deployed satellite network and with an existing communications infrastructure, said network comprising:

at least one atmospheric platform carrying a payload, said at least one atmospheric platform servicing a geographic region;

at least one user equipment unit within said geographic region; and

at least one gateway within said geographic region for securing communications from said atmospheric platform to said at least one user equipment unit and to user equipment units outside said geographic area via said existing communications infrastructure.

2. The network of claim 1 wherein said atmospheric platform is selectively connectable via wireless links with said deployed satellite network.

3. The network of claim 2 wherein said atmospheric platform is an aircraft.

4. The network of claim 3 wherein said aircraft is unpiloted.

5. The network of claim 3 wherein said aircraft is piloted.

6. The network of claim 5 wherein said piloted aircraft is a high altitude long operation aircraft.

7. The network of claim 1 wherein said atmospheric platform flies at an altitude above significant weather, within a narrow band of altitude, and around a fixed point.

8. The network of claim 7 wherein said atmospheric platform flies at an altitude greater than 50,000 feet.

9. The network of claim 8 wherein said narrow band of altitude is in a range between two thousand and ten thousand feet.

10. The network of claim 1 wherein said user equipment units are linked via wireless signals to an antenna carried by said atmospheric platform.

11. The network of claim 1 wherein said user equipment units each include at least one antenna.

12. A star-topology network for providing broadband wireless communication services to ground-based users comprising:

at least one atmospheric platform servicing a geographic area, said atmospheric platform serving as a hub for said star-topology network, and said atmospheric platform carrying a payload comprising communications equipment;

a plurality of user equipment units located within said geographic area and each mounted with at least one antenna having an unobstructed view of said atmospheric platform; and

at least one gateway for providing information pathways from said atmospheric platform to said plurality of user equipment units and to user equipment units beyond said geographic area through an existing communications infrastructure.

13. A star-topology network as claimed in claim 12 wherein said existing communications infrastructure is one of a public switched telephone network, a fiber backbone, and a wideband link capable of carrying communications traffic beyond a metropolitan area.

14. A network as claimed in claim 12, wherein said atmospheric platform is a manned high altitude long operation aircraft.

15. A network as claimed in claim 12 wherein said payload comprises an antenna array, electrical power generation equipment, signal switching circuitry, and receive and transmit radios.

16. A network as claimed in claim 15 wherein said payload further comprises means for distributing electrical power, environmental and thermal controls, and means for determining attitude and position.

17. A network as claimed in claim 16 wherein said payload further comprises means used to position antennas connected to said user equipment units.

18. A network as claimed in claim 12 wherein said payload comprises a first set of antennas for generating a reuse pattern of beams on the ground over said geographic area and a second set of antennas for providing beams that can be directed at specific locations in said reuse pattern.

19. The network of claim 18, wherein said first set of antennas comprises antennas with refractive lenses and said second set of antennas comprises steerable apertures whose beams can be steered by mechanical and electronic means to be stabilized at desired locations on the ground as the atmospheric platform moves.

20. A network as claimed in claim 18 wherein said reuse pattern of beams is in a cellular geometry.

21. A method of providing wireless communications comprising:

providing a star-topology network comprising at least one atmospheric platform carrying a communications payload for servicing a geographic area, a plurality of user equipment units located within said geographic area, and at least one gateway located within said geographic area;

generating a reuse pattern of beams from said payload to said geographic area;

generating beams from said payload that can be directed to desired locations within said reuse pattern;

initiating a wireless communications request and establishing a wireless communication connection through signaling protocols by a first one of said plurality of user equipment units;

selecting a sub-band frequency to be used by a second one of said plurality of ground-based user equipment units for communicating with said atmospheric platform; and

coordinating signaling between said first one and said second one of said user equipment units.

22. The method of claim 21 wherein said selecting step comprises:
transmitting a set of discrete frequency pilot tones by said atmospheric platform, each identifying a sub-band used in said reuse pattern;

sensing the entire set of pilot tones and filtering said pilot tones by said second one of said user equipment units;

coordinating a sub-band used by said second one of said user equipment units with the atmospheric platform.

23. The method of claim 21 wherein said selecting step comprises:

transmitting a unique set of coded pilot tones within a common band of the carrier frequency spectrum, each corresponding to a sub-band used in said reuse pattern;

encoding said pilot tones desired for said unique set;

filtering said encoded pilot tones to extract the coded pilot tones by said second one of said user equipment unit.

24. The method of claim 23 wherein said selecting step further comprises:

transmitting a coded set of pilot tones carrying identifying and diagnostic information;

assessing and monitoring bit error rates and link margin by said second one of said user equipment units to determine an appropriate sub-band.

25. The method of claim 21 wherein said selecting step comprises:

providing said second one of said user equipment unit with means to store a geometric map of beam patterns created by a wireless communications antenna operating in the atmosphere or in space;

providing means for receiving coordinates of the beam pattern of an atmospheric or space antenna through a narrow-band control channel;

selecting a proper sub-band of the communications bandwidth by interpreting messages of coded pilot tones and referencing said geometric map to said coordinates.

26. The network of claim 1 wherein said atmospheric platform determines its position.

27. The network of claim 26 wherein said atmospheric platform determines its position through geometric techniques based on fixed ground reference points.

28. The network of claim 26 wherein said atmospheric platform determines its position through geometric techniques based on multiple ground based transmitters located at known locations.

29. The network of claim 1 further comprising imaging means for providing still and/or video images of any portion of an area serviced by said atmospheric platform, wherein said images are transmitted via said network, and are referenced to coordinates on the ground through geometric techniques.

30. The network of claim 5 wherein said payload further comprises diagnostic equipment for performing operations and systems tests of said network and a graphical user interface for displaying results of said operations and systems tests.

31. The network of claim 30 wherein said results are relayed to the ground.

32. The network of claim 31 wherein said pilot further relays to ground human observations directed to performance of said network.

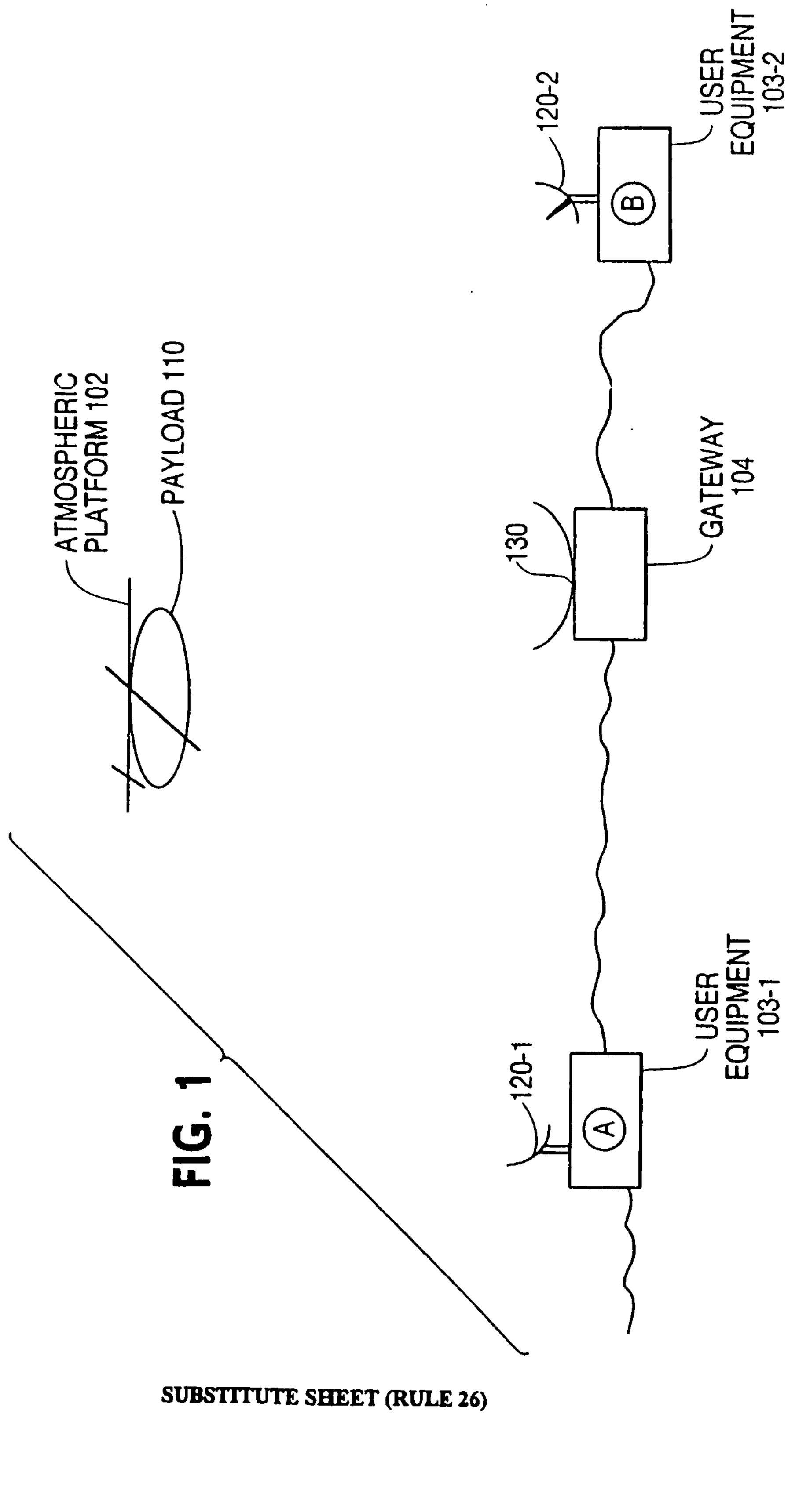
ATMOSPHERIC PLATFORM 102
PAYLOAD 110
120-2
B
USER EQUIPMENT 103-2
130
GATEWAY 104
120-1
A
USER EQUIPMENT 103-1

FIG. 1

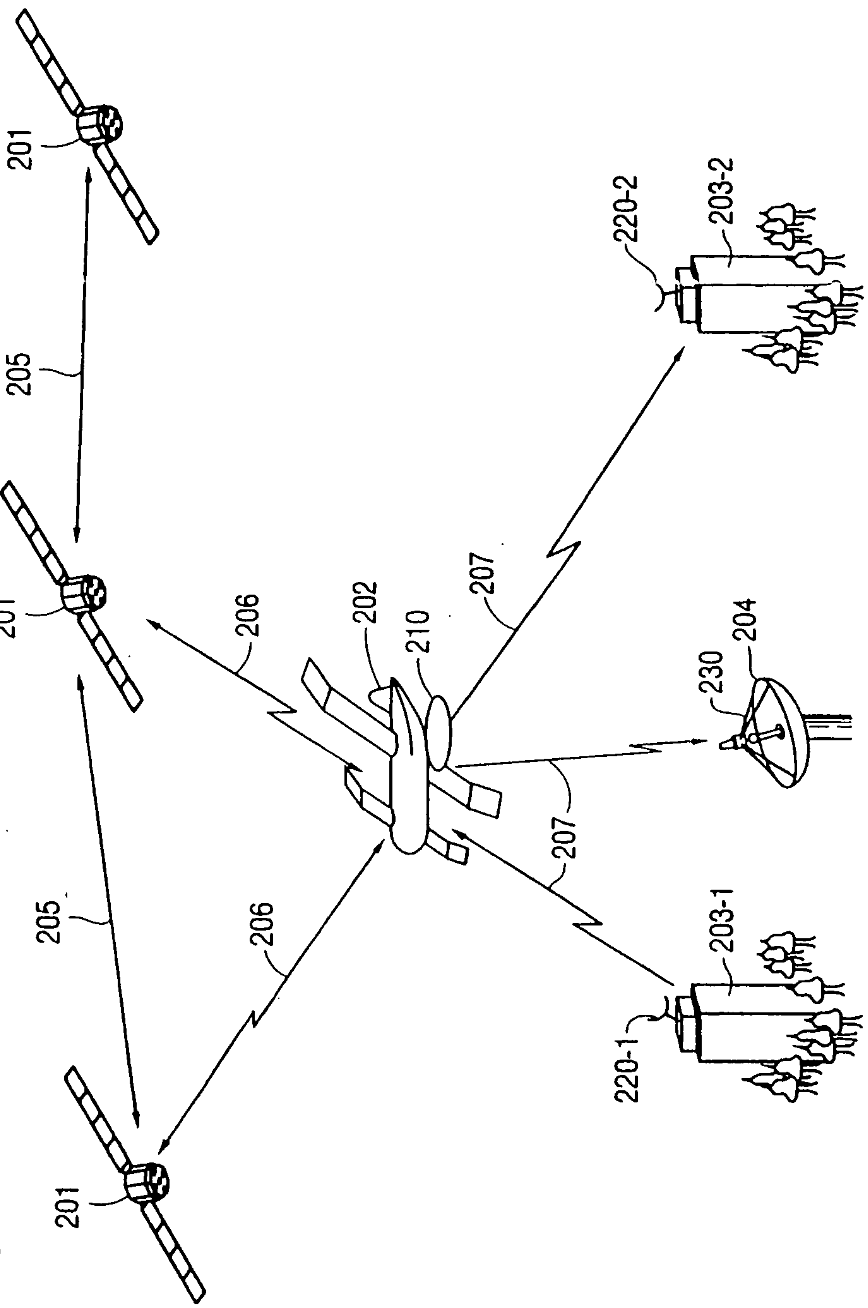
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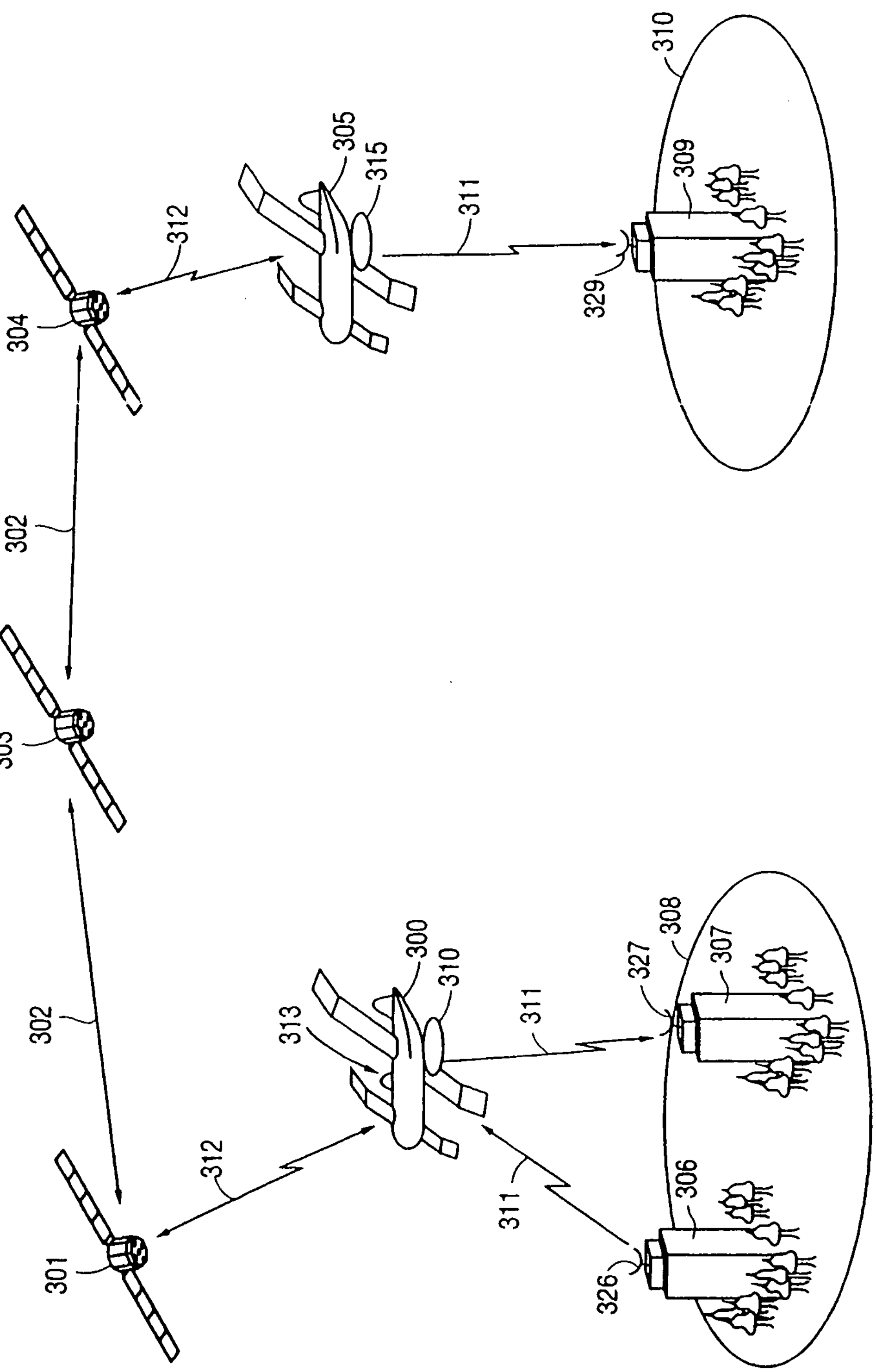
FIG. 2

FIG. 3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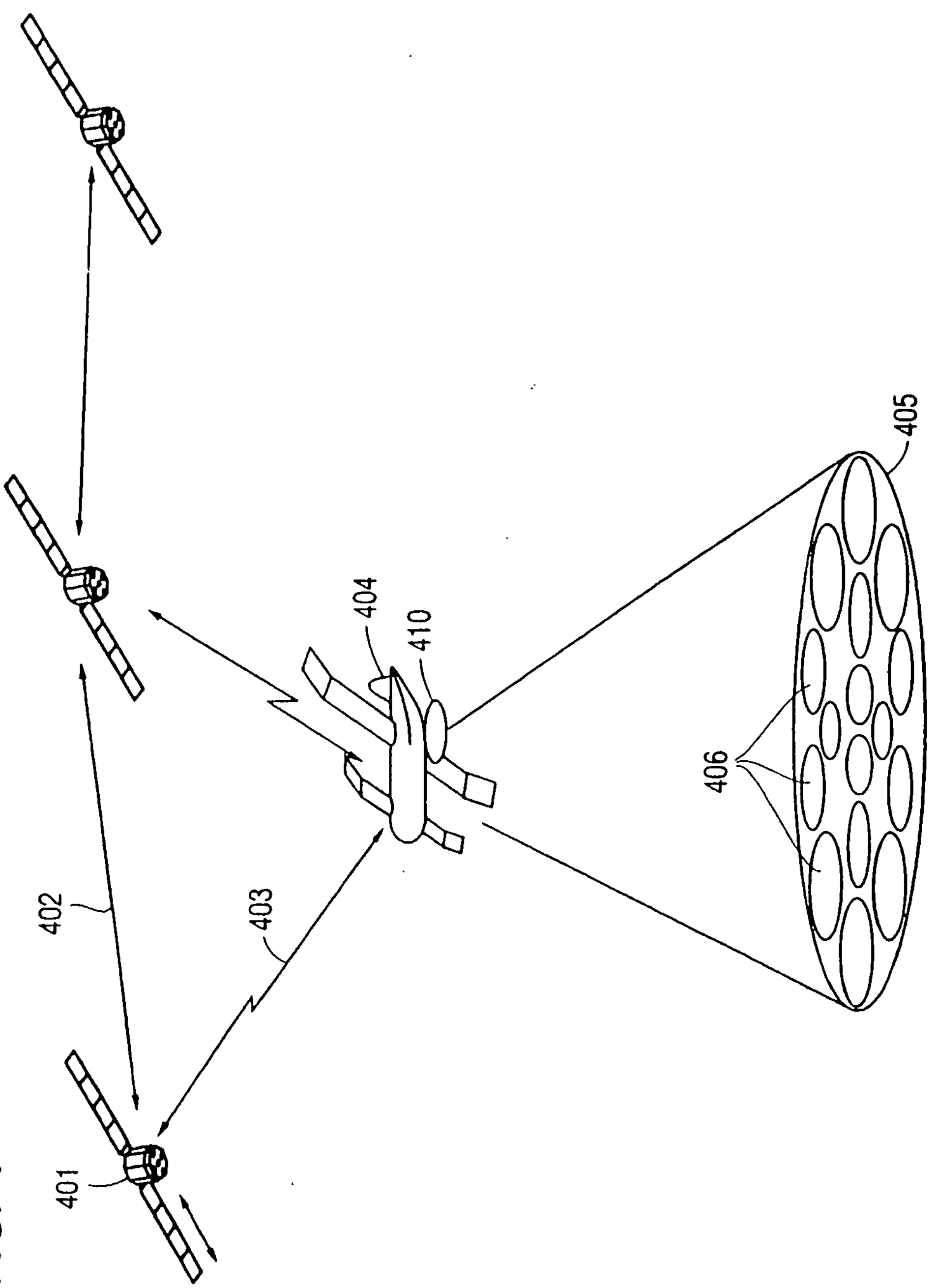

FIG. 4

FIG. 5